3D Printing of Bone And Cartilage Scaffolds With The Help of PLA Material

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Abstract- *In past few decades, tissue engineering is becoming a promising treatment to replace a loss human tissue. In bone and cartilage tissue engineering, a high performance with long term assurance scaffold with customized shape and size is still a tedious process. The major target of this field is to improve to physical, chemical and biological features of the cartilage scaffold and to improve the regenerative property.*

In Additive manufacturing, 3D printing technology is one of the technique which produce customized bone and cartilage scaffold for bone tissue repair. Due to various technological developments on 3D printing and 3D printing objects, there is a possibility to create a novel in the material, shape, structure, mechanical strength, porosity and macro and micro structure.

This project aims to provide the bone cartilage in particular rib cage, with biocompatible and biodegradable material in low cost. Therefore, PLA (Poly Lactic Acid) is the material choice. In this project, the PLA which is one of the polymers is used to replace the loss of rib cage bone tissue and 3D printing technology is incorporated in this bone tissue engineering. To accomplish this, the designing of the rib cage is done with three software's. Therefore, the 3D printing PLA is used as a biomaterial to repair or replace the rib cage.

Keywords- Tissue engineering, Additive manufacturing, 3D printing, PLA, Cartilage scaffold

I. INTRODUCTION

A bone may be a rigid organ that constitutes a part of the vertebrate skeleton in animals. Bones defend the assorted organs of the body, turn out red, and white blood cells, store minerals, give structure and support for the body, and modifies quality. Animal tissue is associated in Nursing avascular, aneural, alymphatic animal tissue found within the secretion joints, spine, ribs, external ears, nose, and airways, and within the growth plates of kids and adolescents. Challenges related to bone and animal tissue diseases embrace poor understanding of the etiology and pathological process, delayed diagnoses because of the aneural nature of the tissue and drug delivery challenges because of the avascular nature of adult cartilages. Risks and complications of the bone and animal tissue surgery is that, as animal tissue repair procedures target the joints, the chance of accidental injury to major organs or blood vessels throughout surgery is negligible. However, there's a little risk of injury to close structures, together with vessels, nerves, or adjacent animal tissue. Bone and cartilage is shown in figure 1.

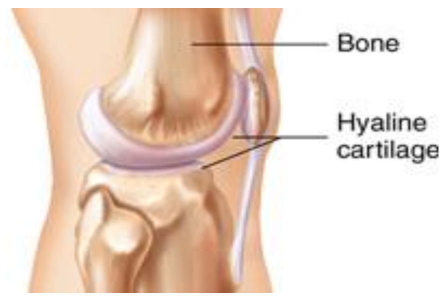
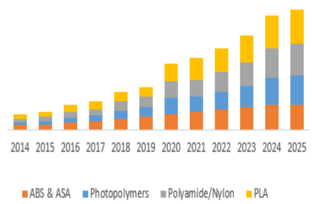


Figure 1: Bone tissue

II. PLA AS IMPLANT BIOMATERIAL

PLA has good mechanical properties such as resistance to high temperature and resistance to hydrolysis, corrosion, and very high tensile strength. Due to the property of biocompatibility it has increased mainly in orthopaedic and trauma cases. Good heat seal ability, easy printability, easy to cast. PLA has a good versatility in fabrication, compatibility with bio molecules and cells.

PLA is employed in bone surgery at the skeletal sites that don't seem to be expected to face up to significant load. So as to boost PLA strength, its osteo integration and radio-controlled degradation, numerous PLA-based composites square measure created. 3D written PLA implants guarantee mechanical stability; possess a high biocompatibility and osteo conductivity. PLA will degrade into innocuous carboxylic acid; therefore it's used as medical implants within the kind of anchors, screws, plates, pins, rods, and as a mesh. PLA also can be used as a complex packaging material, solid, injection-molded, or spun. PLA is wide employed in tissue engineering and it finds a good spectrum of applications within the medical field. They being extensively used as biomaterials within the fields of controlled drug delivery systems, tissue regeneration and as alternatives for alternative ceramic based mostly chemical compound materials scale back impact on surroundings. The graph analysis of the PLA material in recent years is shown in the figure 2.



Attribute	Details
Base Year	2017
Historic Analysis	2014-2016
Forecast	2018 to 2025
Complete Free Customization*	Equivalent to 50 analyst hours

Figure 2: Graph analysis of PLA

3D printing is the next generation of the fabrication technique which has been extensively used inside the region of research along with engineering, biology, chemistry, computer science and material technology. In our venture we are going to print the bone and cartilage scaffold by means of the use of PLA materials. Polylactic acid or Polylactide (PLA) is a thermoplastic aliphatic polyester derived from renewable belongings.

- Biodegradability
- Good biocompatibility
- Good process ability.

PLA is considered a complicated biomaterial used in clinical implants, e.g., use with a excessive-decision magnetic resonance imaging (MRI), for developing a partial replacement cranium in neurosurgical packages. PLA printed scaffolds are shown in the figure 3.

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Figure 3: 3D printed PLA scaffolds

Thus, in our project it is to 3d print the scaffolds which thereby help in solving difficult medical problems. It can have various innovations and can be used to solve surgical problems, stress based problems can also be solved since it has low elastic modulus.

III. BIOMEDICAL SIGNIFICANCE OF PLA

Polylactide (PLA) and its copolymers are the aliphatic polyesters possessing exclusive homes like good bio-compatibility, biodegradability by enzyme and hydrolysis under physiological conditions, low immunogenicity, and so on. Because of such capabilities they've attracted interest and first-rate interest as progressive materials for a wide range of applications in biomedical and pharmaceutical programs, e.g. drug shipping structures, sutures, implants for bone fixation, etc. A comprehensive literature seeks well-known shows the applications of PLA and its polymeric composites in medical fields including: Orthopaedics, Drug companies, Facial fracture repair, Tissue engineering, Biomaterials. Figure 4 shows the 3D printed composite sternum and rib cage.

Figure 4: 3D printed composite sternum and rib cage

Table 1: Properties of PLA

S.NO	PROPERIES	RANGE	UNIT
1.	Viscosity range	0.265-0.467	mPa-s
2.	Density	1.25	gm/cm^3
3.	Yield tensile strength	53	MPa
4.	% Yield elongation	11-100	%
5.	Melting point	115-175	°C
6.	Shear modulus	2.4	GPa
7.	Specific heat	1800	J/Kg°K
8.	Glass transition temperature	54-56	°C

IV. ORTHOPEDICS APPLICTIONS OF PLA

The investigation of bio-absorbable implants for fixation in orthopaedics is unexpectedly growing. PLA and its co-polymers with glycolic acid and other hydroxyl acids are substances of high significance for orthopaedic packages. The usage of absorbable substances in place of traditional metallic devices has been outstanding when you consider that 1965. First PLA suture used for fracture fixation plates and screws was patented in 1973. Figure 5 shows the 3D printed PLA orthopaedic screws.

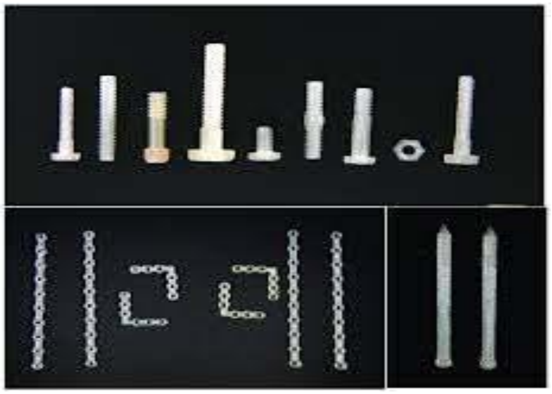


Figure 5: 3D printed PLA orthopaedic screws

Bio-absorbable fixation gadgets are drastically applicable in orthopaedic and craniomaxilla facial surgical treatment. Such gadgets and ultra excessive-energy implants are especially composed of PLA and/or PGA polymers. They may be usually used for the stabilization of fractures, bone grafting, reattachment of ligaments, tendons, and so on. PLA polymers lessen dangers for the duration of pre-implant osteoporosis and risks bobbing up because of infections.

V. PROPOSED METHOD

The current method which is widely used for defective bone replacements employs titanium as the main material for the 3d printing of the replaceable part. The main disadvantage of using titanium is that the body rejection in many patients, which is of main concern and which has left to less success rate , when employed in the crucial parts of the body, say, the rib cage.

VII. DIMENSIONS

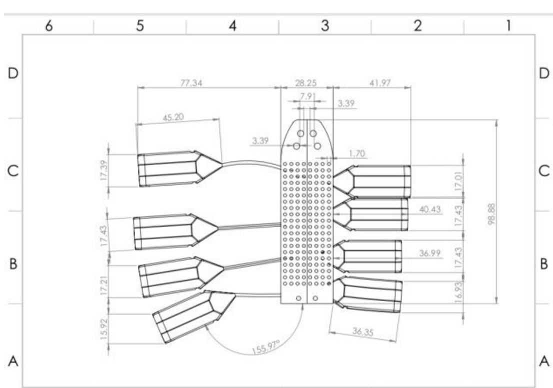


Figure 6: Top view of the part

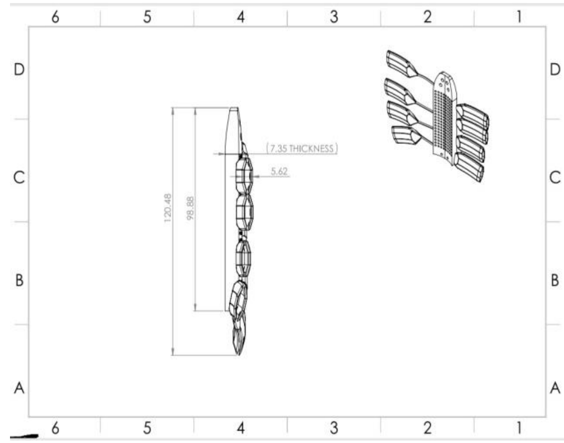


Figure 7: Side view of the part

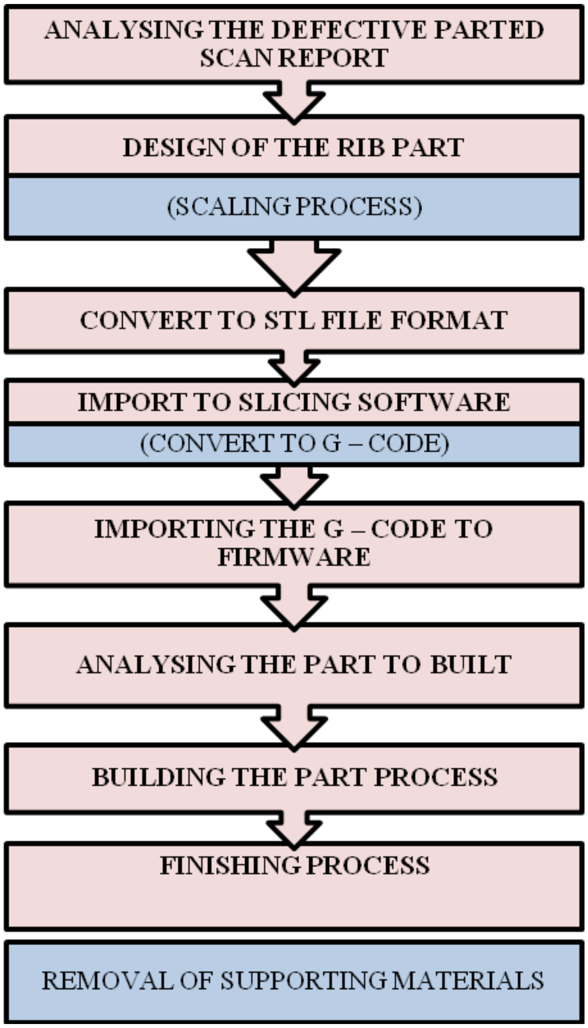
Figure 6 and figure 7 shows the top and side view of the rib part. The whole model is designed using the SolidWorks, Cura software and Marlin firmware and is printed with the 3D printers with the help of raw block of material of PLA.

VIII. WORK FLOW OF 3D PRINTING

Initially, the defective part's scanned copy is analyzed. The defective part may be due to any accidents, trauma or damages. Following the defective part, designing of the rib part is made with exact dimensions of the defective one. Then convert the designing to STL (Standard Triangular Language) format using SolidWorks software. Then the STL file format is imported to the slicing software called Cura software, generation of specific G-code. After this the G-code is imported to Marlin firmware, used to run coded commands and instruction sets. Later, the rib part that is needed to build is analyzed for the parameters and then the building of the part is processed. The printing is processed and the final finishing process is done. And finally, the rib part is made and the supporting materials are removed. Then the product is tested and is attached to the specific target part by surgery.

The work flow chart shown in the table 2 illustrates the proposed system.

Table 2: Work Flow



IX. PROCESS OF 3D PRINTING

SoildWorks Model Creation: ab initio, the item to be 3D written is intended utilizing a software system (SolidWorks) software package. Solid modelers, for instance, CATIA, and SolidWorks have bent represent 3D objects additional exactly than wire-frame modelers. This procedure is comparative for the bulk of the speedy Prototyping building strategies.

Conversion to STL format: completely different from the various SolidWorks models, different strategies to gift solid elements. To possess consistency, the stereo lithography has been followed because of the commonplace of the 3D printing trade.

Slice the STL file: A pre-processing malicious program is completed that reads the STL format getting to be designed. The pre-processing program cuts the stereo lithography model into varied layers from 0.01 mm to 0.7 mm thickness. The program makes an associate in nursing auxiliary structure to assist the model amidst building. Subtle structure square measure certain to use auxiliary support.

Layer by layer construction: the fourth step is the actual construction of the half victimization one in every of numerous techniques. RP machines build one layer at a time from polymers or fine-graded metal.

The designing part of the rib is shown in figure 8.

X. DESIGNING OF THE RIB

When taken into account the rib cage, the rib cage has motional abilities due to the exhalation and inhalation process. Thereby, along with the sternum, the rib bones are designed with a socket, to facilitate smooth expansion and relaxation of the entire rib cage structure. The rib model is designed using SolidWorks software. Using the software, the dimensions and the required part is loaded into STL file. The designing part of the rib is shown in the figure 8.

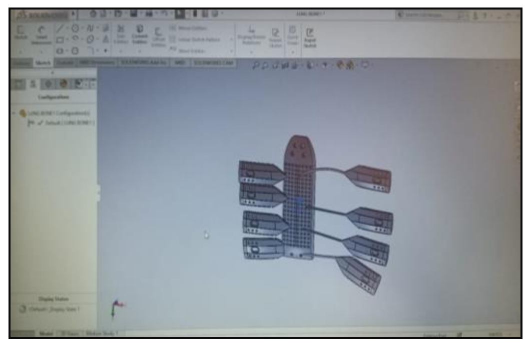


Figure 8: Designing part of the rib

XI. RESULTS AND DISCUSSIONS

When taken into account the rib cage, the rib cage has motional abilities due to the exhalation and inhalation process. Thereby, along with the sternum, the rib bones are designed with a socket, to facilitate smooth expansion and relaxation of the entire rib cage structure. The figure 9 shows the output 3D printed rib part with the help of PLA material using FDM method.

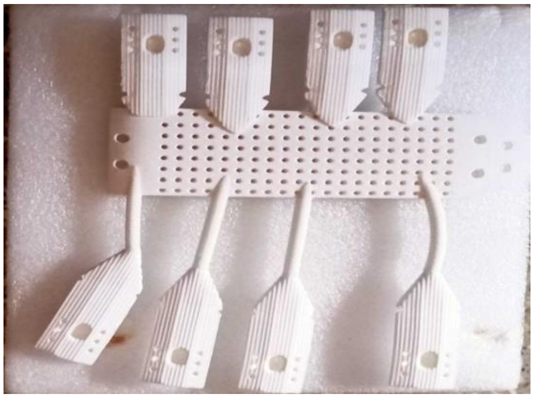


Figure 9: Output

XII. CONCLUSION

The proposed method using PLA is found to be easy available and easy to fabricate, user friendly and cost effective, which can be readily available for patients. Though it is designed keeping in mind about the need for hospital, it can be extend for other purposes such as commercial and research applications. In FFF method of 3D printing, the printing is done by obtaining output with a short period of time.

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